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To cite this article: A Yuliawati *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **434** 012107

IOP Conf. Series: Materials Science and Engineering **434** (2018) 012107 doi:10.1088/1757-899X/434/1/012107

Minimum viable population estimation of Timor Deer (Rusa timorensis) base on demographic parameters

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Abstract. Timor Deer (Rusa Timorensis) population in Pananjung Pangandaran Natural Park and Nature Reserve is decreasing. Conservation is needed to reduce the rate of population decline. Minimum viable population (MVP) is the basic information that need to know as management tool for conservation. MVP is the minimum population size that will ensure the viability of a species in a given period of time. MVP of more than a thousand species was determine generally, whereas specific MVP for every age class is necessary for efficient conservation strategy. On this study we estimate MVP of Timor Deer base on demographic parameters using Algebra linear equation system from matrix Leslie model to get specific MVP size for every age class. MVP size for Timor deer in Pananjung Pangandaran Natural Park and Nature Reserve is 97 individuals, with the composition of 32 juveniles, 47 sub-adults, and 18 adults. The actual Timor Deer population is 68 individuals with the composition of 16 juveniles, 21 sub-adults, and 31 adults. Base on this study, we have to increase juvenile and sub-adult population to ensure the viability of Timor Deer in Pananjung Pangandaran nature park and nature reserve.

1. Introduction

The population of Timor Deer continues to decline with a population decline rate of 10% in each generation [1]. The declining population also happen in Pananjung Pangandaran Natural Park and Nature reserve. Habitat lost, poaching, and natural disasters are some factor that reduce wildlife populations. The main objective of conservation is to reduce and prevent the declining population [2]. Conservation can be undertaken by managing wildlife populations, because extinction and sustainability are determined by population size [3], [4]. In population management, information on the actual population and the target population is important. The minimum viable population size can be a target of the conservation effort [5]. MVP also can be used to determine the conservation policy [6].

Minimum viable population (MVP) states the threshold of the population size of a species in individual units ensuring that the population will survive for a period of time [7]. Shaffer [7] defines MVP for the various species found in each habitat as the smallest isolated population that has a 99% chance of survival or survival for 1000 years after gaining demographic, environmental, genetic and natural disasters. Meanwhile, according to Reed [8] MVP is the smallest population of a species that has 99% probability to persist for 40 generations.

First concept of MVP (Minimum Viable Population) initiated by Shaffer in 1981 [7], MVP has gained more attention in the field of biological conservation. Genetic and evolutionary processes are among the guidelines for predicting the minimum population for a species to survive. To avoid short-term inbreeding pressures, Franklin [9] proposed that the minimum effective population size not less than 50 individuals, based on the minimum size theory of inbreeding 1% in each generation. This inbreeding measure has been considered with tolerance for many domestic animal species conditioned in a harmless environment.

So far, MVP of more than a thousand species was determine generally. [9] Proposes 50/500 to be used by conservation practitioners, where effective population values are needed to prevent unacceptable inbreeding rates, while an effective population rate of 500 is required to keep the entire genetic variety in the long run. In 2002 Frankham [10] determined MVP from genetic point of view, the estimated value of the effective population of 50 individuals is the prevention of inbreeding pressure, 12 to 1000 to avoid the accumulation of mutations that can eliminate some gene varieties, and 500-5000 to withstand evolutionary potential. Based on the average effective population value divided by the population rough value, worth about 0.100 or 10% then we must have 500 individuals out of 5000 individuals in the census [10]. In 2011 Frankham make some revision about that number. His research state that 50 individuals not sufficient for inbreeding depression prevention. And 500 individuals is too low for retaining evolutionary potential for fitness in perpetuity; a better approximation of effective population is more than 1000 individuals [11]. In line with Frankham, Traill [12] also criticized the theory of minimum viable population size. His research show that to ensure the population viability need thousands individuals. Minimum Viable population for long-live species such as bog turtle, only need 15 breeding female to ensure the viability for more than a hundred years [13] whereas every species have deferent demography parameters that lead to have deferent MVP size. Even in every age class. Therefore on this study we estimate the specific MVP for Timor Deer in Natural Park and Nature Reserve.

2. Method

2.1. Demography parameters

To estimate Timor Deer MVP base on demography parameters we need actual population size, age class, sex ratio, survival rate, fecundity, and breeding age. Population size, sex ratio, and age class was counted directly by concentration count census method in 6 pastures that used by Timor Deer for grassing. Population size was counted simultaneously in 6 pastures at 06.00-08.00 a.m. and 16.00 – 18.00 p.m.

2.1.1. Survival *rate.* Age specific survival rate (P_x) was obtained from the number of individuals living in the age class x + 1 in year t + 1 (L_{x+1}) divided by the number of individuals in the age class x in year t (L_x) as in the following formula:

$$P_x = \frac{L_{x+1}}{L_x} \tag{1}$$

2.1.2. Fecundity. Caughley and Sinclair [14] state that fecundity rate is a number of female live births per female per unit of time. We obtained fecundity (Fx) from female juvenile population (x) divided by sub-adult/adult female population (B) as in the formula below:

$$Fx = \frac{x}{B} \tag{2}$$

2.1.3. Minimum viable population. Viability will be achieved when at least the final population is equal to the initial population or increased. In other words:

$$N0 = N1 = N2 = Nt \tag{3}$$

- N0 = current juvenile population (A0) + current Sub-adult population (R0) + current adult population (D0)
- N1 = juvenile population at the first year (A1) + sub-adult population at the first year (R1) + adult population at the first year (D1)
- N2 = juvenile population at second year (A2) + sub-adult population at second year (R2) + adult population at second year (D2)
- Nt = Juvenile population at year t (At) + sub-adult population at year t (Rt) + adult population at year t (Dt)

Population size every age class obtained base on Leslie matrix below that has been modified by Priyono [15].

$$\begin{vmatrix} A_1 \\ R_1 \\ D_1 \end{vmatrix} = \begin{vmatrix} \delta_A & F_m & F_d \\ p_1 & \delta_R & 0 \\ 0 & P_2 & \delta_D \end{vmatrix} \text{X} \begin{vmatrix} A_0 \\ R_0 \\ D_0 \end{vmatrix}$$

Fx = Age specific fecundity
Px = Age specific survival
δx = members of population x who remained in the same age class at the following year

From Leslie's matrix, a linear algebraic equation was developed. The minimum viable population size is determined by the elimination method of the equation. The equations are:

$N0 = A + R + D$
$N1 = (F.\ R+F.D+\delta A)+ [(A.P1) + (\delta R)] + [(1\text{-}\delta R)R.P2) + \delta_D D]$
$N2 = \{F.\ [(A.P1) + (\delta RR)] +F.\ [(1\text{-}\delta R)R.P2+ \delta_D D] +\delta A[F.R + F.D + (\delta AA)]\} + \{[P1.\ (F.R+F.D+ (\delta AA)] + \delta_R [(A.P1) +(\delta RR)]\} +\{P2.\ (1\text{-}\delta R)[(A.P1) + (\delta RR)] + \delta_D [(1\text{-}\delta R)R.P2) + \delta_D D]\}$

2.1.4. Population modeling. Initial population projected per year by using matrix Leslie Density Dependence, so the population growth can be predict. We projected the population for 100 years. Leslie matrix projection is only for the female population. The population size of males is obtained by comparison of sex ratio. Multiplication matrix assisted with Microsoft Excel 2007.
Matrix equation of the density dependence used is as follows:

$$M \times Q_t^{-1} \times N_t = N_{t+1}$$

$$M = \begin{bmatrix} F_a & F_r & F_d \\ P_0 & 0 & 0 \\ 0 & P_1 & 0 \end{bmatrix} \qquad N_t = \begin{bmatrix} N_{a,t} \\ N_{r,t} \\ N_{d,t} \end{bmatrix} \qquad Q_t^{-1} = \begin{bmatrix} \frac{1}{q_{0t}} & 0 & 0 \\ 0 & \frac{1}{q_{1t}} & 0 \\ 0 & 0 & \frac{1}{q_{2t}} \end{bmatrix}$$

Information:

Fx = age specific fecundity
Px = Age specific survival rate
N_t = population size at year t
Q = growth limiting factor
$q_t = 1 + \alpha. N_t$
$\alpha = (\lambda-1)/ K$
$\lambda = e^r$ (finite rate of increase)
r = population growth rate
K = Carrying Capacity

3. Result and discussion

3.1. Population size, age class and sex ratio

Population size of Timor Deer in Pananjung Pangandaran Natural Park and Nature Reserve in 2011 is 68 individuals. This number was the highest population size of 6 times repetition census. Age class and sex ratio of Timor Deer are arranged in population pyramid on figure 1. The figure show that the type of Timor deer population pyramid is expansive, where the juvenile population size is larger than sub-adult population size and adult population size. It Show that the population is developing. The pyramid also shows the sex ratio between male (buck) and female (doe) in each age class. Sex ratio of sub-adult buck and doe is 1: 2 whereas sex ratio of adult buck and doe is 1: 1,2. In general, the sex ratio condition in the population is quite normal where the population of doe is larger than buck's population. Therefore, in order to optimize the population condition, it is necessary to increase the female deer population in Pananjung Pangandaran Natural Park and Nature Reserve.

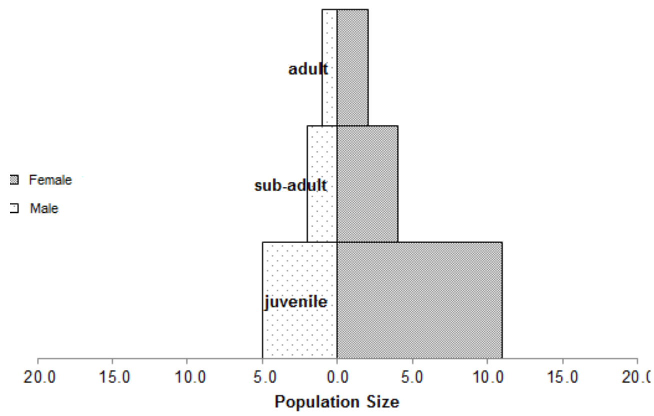

Figure 1. Population pyramid.

3.2. Survival rate

Survival rate is the ability of individuals of certain age classes to live in the age class above it. In the ecological study survival rate also called as survivorship. Every organism has different types of survivorship. Based on this study the survivorship type of Timor Deer is type 1 which is population after birth does not decrease drastically, tend to survive and experience a drastic decrease in certain age [16]. The survival rate of juvenile to sub-adult are very small it is only 0.375 or 37.5% of the juvenile population that can survive in the next age class. The survival rate of sub-adult to adult age class is 0.5 or 50% of the sub-adult population that can continue living in adult age class. Survival rate was deferent in every age class and also region specific [17].

3.3. Fecundity
Fecundity is the ability of the female to produce offspring in a period of birth. Fecundity in large mammals usually calculated for a period of one year [3]. In this study, fecundity was calculated by dividing the number of female infant population by the number of female productive population. Breeding age for doe is 1.5 -12 years old [18]. In ecology we know the term of potential fecundity and realized fecundity [16]. Potential fecundity is the ability of a female to produce infant in a period of birth in theory, whereas realized fecundity is the ability of a female to produce infant in a period of birth in the real life. Deer potential fecundity is one infant every birth period [16, 18]. Based on this research, realize fecundity of Timor Deer in Pananjung Pangandaran is 0.6 infant/year. The realized fecundity show that in one year the doe can produce one infant but is less likely to giving birth again in the next year. Many Factor that can affected fecundity, such as the nutritional intake and body reserves.

3.4. Minimum population size
We obtain the minimum viable population estimation from the calculation of linear algebra is only performed on the female population. The minimum viable population size for males is obtained by comparison of sex ratio. From the calculation result the minimum viable population size in Pananjung Pangandaran Natural Park and nature reserve are as follows:

Table 1. Minimum viable population size.

Age Class	Sex	MVP size
Juvenile	Male	11
	Female	21
Sub- adult	Male	16
	Female	31
Adult	Male	8
	Female	10
Total		97

The minimum sustainable population size varies across species and in each population, depending on demographic, environmental and genetic factors [7]. The minimum viable population size of Asian elephants calculated by [19] using Vortex software shows different population sizes in two populations with different population growth rates. 25-30 individuals for Asian elephant population with growth rate 0,02 (2% per year) and 65-80 individuals for population with lower growth rate that is 0,005 (0,5% per year). Harcourt [20] States that the minimum sustainable population size in primates also varies according to the area.

3.5. Population modeling
The population growth was perform by Matrix Leslie model with density dependence, with carrying capacity as a limiting factor. We omitted another limiting factors such as disease, and catastrophic stochastic effects because of limited data. Figure 2. Show that the population of Timor deer will increasing until the population size is approaching carrying capacity. Base on the Leslie matrix projection with density dependent model, Timor Deer minimum viable population in Pananjung Pangandaran will be reach in 2020.

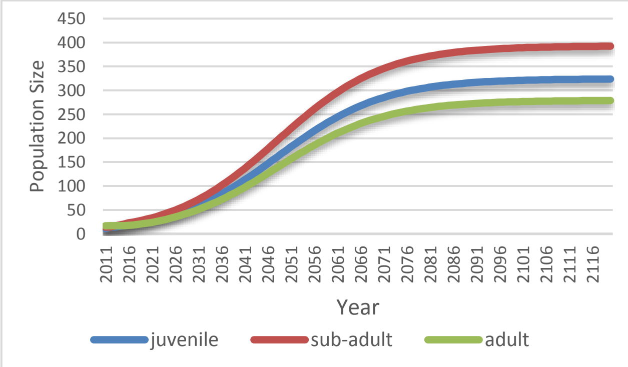

Figure 2. Rusa Timor population growth.

4. Conclusion

Estimation of Minimum viable population for Timor Deer in Pananjung Pangandaran Nature Reserve is 97 individuals with the composition of 32 juveniles, 47 sub-adults, and 18 adults. The population still need more juvenile and sub-adult individuals to achieve the minimum viable population. Base on the population modelling, Timor Deer minimum viable population will be achieve in 2020.

Acknowledgement

We gratefully acknowledge forest rangers in Pananjung Pangandaran Natural Park and Nature Reserve for their assistance during this research. We also thank all those who contributed to the data analysis and writing of this paper.

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